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A HRTEM/EDX approach to identification of the source of dust particles on urban tree leaves

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ABSTRACT

Dust on tree leaves in the urban area of Hangzhou, China, was analyzed in terms of heavy metal contents and magnetic properties. Morphological and chemical composition of the dust particles were analyzed using a high resolution transmission electron microscope equipped with an energy-dispersive X-ray analyzer (HRTEM/EDX). Results indicated that the dusts contained high concentrations of Cd (mean 2.62), Cu (63.7), Zn (535.9) and Pb (150.9 mg kg^{-1}). Magnetic susceptibility of the dusts was in a range of $(16–856) \times 10^{-8}$ m^3 kg^{-1}. It was shown that the dusts close to industrial area and busy road intersection had higher heavy metal contents and magnetic susceptibility. The dusts showed a strong positive inter-correlation for the concentrations of Fe, Mn, Cr, Zn, Pb, and Cu in addition to magnetic susceptibility, which suggests that the dusts had a common source for the heavy metals and magnetic carriers. We found that the dust particles were composed mainly of Fe-rich near-spherical, plate and agglomerate particles, and Ca-rich, S-rich and silicate particles, and that iron oxide spherules (0.2–0.5 μm in diameter) and larger iron-bearing particles were the magnetic carriers. Ca in the dusts was present in the forms of $CaCO_3$ and $CaCO_3/CaSO_4$ internal mixture. The Fe-rich, Ca-rich and S-rich particles in dusts could be directly related to nearby polluting activities, such as coal combustion, traffic emission and industrial activity. The identification of the main sources of dusts on tree leaves can help in controlling the polluting sources in urban areas. The close correlation between magnetic susceptibility and heavy metal concentration makes it possible to use the magnetic technique as a non-destructive and time-efficient tool for biomonitoring of the atmospheric dust pollutants.

1. Introduction

Urban atmospheric dusts were reported to adversely effect human's health (Donaldson et al., 1998; Harrison and Yin, 2000; Zhao et al., 2006). Airborne particles with a diameter less than 10 μm (PM_{10}) are highly hazardous since they easily enter respiratory system of the human and hurt the respiratory system. Epidemiologic studies (Samet et al., 2000) have shown that the increased mortality and morbidity from respiratory and cardiovascular diseases were associated with the mass concentration of such airborne particles. Hence, there is a need to identify the sources and constituents of these urban particulate matters (PM). Tree leaves in the urban area have been reported as a good accumulator of the atmosphere dusts (Eriksson et al., 1989; Moreno et al., 2003; Urbat et al., 2004). Tree leaves, such as conifer needles and evergreen tree leaves, can efficiently accumulate dusts due to their large surface area and waxy coating surface. Tree leaves in roadside and urban areas are commonly polluted by

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particulate matter (PM) mostly related to the traffic/motor vehicle emission, abrasion of tyres, brake linings as well as road surface cycling of dust in suspension due to vehicular movement, dispersion of construction material, etc. (Gautam et al., 2005; Goddu et al., 2004; Matzka and Maher, 1999; Prajapati et al., 2006). Due to wide distribution of trees, the tree leaves allow the construction of sampling grids of different scales with high density of sampling points and spatial resolution, which otherwise are difficult to achieve in a monitoring station. Thus, tree leaves can be used to determine the spatial and temporal distribution of atmospheric dusts (Davila et al., 2006; Eriksson et al., 1989; Hanesch et al., 2003; Urbat et al., 2004).

Due to high content of the magnetic minerals in urban PM, the magnetic techniques have been increasingly used to assess the urban PM (Gautam et al., 2005; Goddu et al., 2004; Kim et al., 2007; Matzka and Maher, 1999; Muxworthy et al., 2001, 2003; Shu et al., 2001). The magnetic minerals in atmosphere are mainly derived from combustion processes, such as industrial, domestic and vehicle emissions (Hunt et al., 1984; Triantafyllou, 2003) or from abrasion products from asphalt and from vehicles brake systems (Gautam et al., 2005; Goddu et al., 2004; Hoffmann et al., 1999). In particular, the magnetic minerals in aerosols are associated with these heavy metals such as zinc, cadmium and chrome (Hunt et al., 1984; Gautam et al., 2005; Goddu et al., 2004; Petaloti et al., 2006) and with mutagenic organic compounds (Morris et al., 1995), which were reported dangerous to health of the human. The excellent potential of environmental magnetism as a proxy for atmospheric pollution levels has been reported based on analysis of vegetation samples including tree bark and leaves or needles (Kim et al., 2007; Matzka and Maher, 1999; Jordanova et al., 2003; Moreno et al., 2003). Magnetic properties of the leaf dusts (Davila et al., 2006; Hanesch et al., 2003; Matzka and Maher, 1999; Triantafyllou, 2003) have been used for identification of the spreading of pollutants derived from vehicular or industrial emissions. Magnetic susceptibility provides a first indication of the concentration of ferrimagnetic minerals in the dusts. Hence, magnetic measurements on the dusts can serve as a complementary tool for the routinely used geochemical methods, which are known time-consuming, tedious and expensive.

Although the study on the atmospheric mineral particles has started for many years in arid regions, the knowledge on atmospheric mineral particles over the humid subtropical area is still very meager. The complexity of airborne dust particles makes their characterization and source identification difficult. The source of dust particles is of particular importance for evaluation of the atmospheric pollution, however, the knowledge on it is very limited by now. There are few studies dealing with this problem by using scanning electron microscopy (SEM),

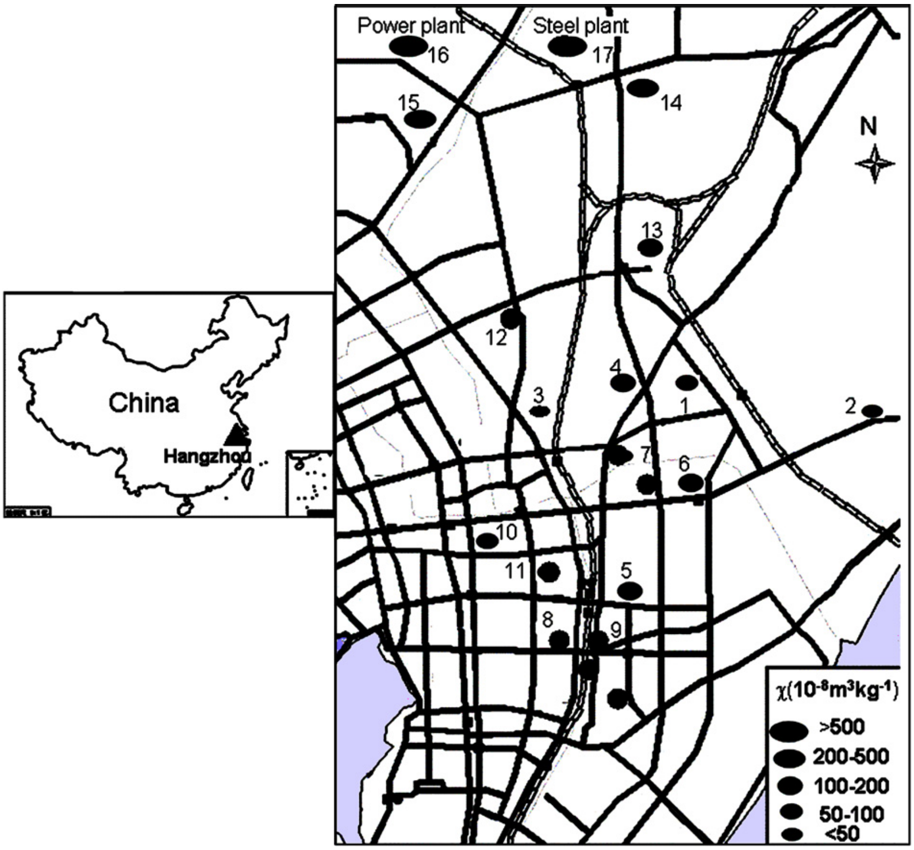

Fig. 1. Sketch map showing the sampling locations. The dark lines indicate the major road.